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SCIENCE AND SENSE IN THE INOCULATION OF LEGUMES.

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This circular is issued in answer to numerous inquiries from that class of Illinois farmers who are helping to place the business of farming on a practical scientific basis, and who are now asking for reliable information concerning the widely advertised nitrogen bacteria now being offered for sale by seedsmen.

Like many other things that have merit, the necessity for inoculation and the benefits to be derived from it are being greatly exaggerated and over-estimated.

One 1905 seed catalog advertises as follows:

"NITRO-CULTURE.

A WONDERFUL DISCOVERY.

DOUBLES THE YIELD.

Insures Crops of Alfalfa and Other Leguminous Plants on all Soils.

"Nitro-culture is a germ, sold in dry packages like yeast cake . . . . . .

"For some years it has been thought that the only way was to inoculate the soil, that is, to bring soil from localities where the particular crop had been grown successfully and scatter it on the land. But this method was very expensive and inconvenient. Finally it was discovered by one of the scientific men in the Agricultural Department at Washington that the same results could be secured by inoculating the seed instead of the soil. Nitro-culture is the result and it is now offered for sale . . . . . .

"Price, postpaid, package sufficient for one acre $2.00."

"For $2.00 per acre you can be absolutely sure of a heavy crop of alfalfa the first year after seeding."

For each grain of truth in this advertisement, there are at least ten grains of error or deception. Seed inoculation is not a new discovery. It has been practiced for some fifteen years. Ten years ago it was being widely advertised in Germany by German promoters who undertook to establish the business of selling nitrogen bacteria for inoculating seed. Just now American promoters are engaging in the same business and they are endeavoring to strengthen their claims by erroneous or misleading references to the work of experiment stations and departments of agriculture.

It is true that nitrogen-fixing bacteria are essential to the most successful growing of legumes, but it is also true that as a very general rule the proper bacteria are already present in the soil, especially for the more common legumes, as the ordinary clovers and cow peas.

It is not true that inoculation "insures crops of alfalfa and other leguminous plants on all soils." Failure of legumes may be due to soil acidity. It may be due to insufficient mineral plant food, as phosphorus or potassium. It may be due to insufficient organic matter and consequent improper physical conditions. It may be due to lack of proper underdrainage. It may be due to the fact that the soil or the subsoil is not suited to the requirements of the plants. It may be due to an unfavorable season, which may be too dry or too wet, too hot or too cold, but which may be favorable for the development of foul grass and weeds. In none of these cases would inoculation remedy the difficulty.

It is not true that inoculation "doubles the yield," except in the somewhat rare instances where all other conditions are favorable while the bacteria are lacking.

It is not true in most cases that to inoculate with soil is "very expensive and inconvenient." Indeed the accumulated practical experience of the past fifteen years and the data thus far reported from comparative experiments combine to prove that the simplest and surest and most economical method of inoculation is by means of well infected natural soil, collected where the proper bacteria are present in abundance (as shown by the tubercles on the roots of the plants) and scattered over the field to be seeded at the rate of 100 pounds or more per acre. If special care is taken to scatter the infected soil over all the ridges, or water sheds, the bacteria will soon be carried over the rest of the field by surface drainage waters. If the infected soil is applied with manure it can be done with practically no extra trouble or expense. For those who use fertilizer drills with a double box, the

grain box may be used for the seed (such as soy beans) and the infected soil can be run through the fertilizer box into the same drill rows. The writer had 40 acres of soy beans seeded and inoculated in this way on his own farm in 1904, and the infection obtained was very satisfactory, abundance of root tubercles being found where the infected soil was seeded with the beans, while on a check strip, seeded without infected soil, no tubercles could be found.

It is true that seed inoculation can be successfully performed. One can take a vessel of pure water, bring it to the requisite temperature, add the bacteria culture and a nutrient material, allow it to stand at an approximately uniform temperature for a certain number of hours, then add another nutrient material and again allow it to stand, the temperature still being controlled by means of the thermometer and some artificial heat if necessary, until certain reactions or visible changes occur, then moisten the seed with the solution, and then spread it out to dry where it will not mould or sprout or lose its vitality or be subject to conditions which will destroy the bacteria with which it has become infected. All this is easily done by the chemist or bacteriologist, and it can be done by a careful farmer who has the facilities and who can take the necessary time and pains. Indeed, it is assumed that most failures resulting from attempted seed inoculation, not only in the earlier trials with German cultures, but also in recent years with American cultures, are due chiefly to the fact that the farmers "failed to follow directions."

Clover Bacteria.

These are certainly present in great abundance in nearly all soils in central and northern Illinois. If they are not present in some field or on the higher lying parts of the field, they can easily be supplied by means of well infected soil taken from other parts of the field or farm, or by an application of manure made from clover hay. Even in southern Illinois good patches of clover well infected with bacteria can usually be found within easy hauling distance, either on bottom land, or on well manured fields.

Cow Pea Bacteria.

These are found to be present in nearly all parts of the state so that wherever cow peas are seeded some tubercles appear even the first year, while the second year (and often the first year) they develop in abundance. If a few cow peas are seeded in the corn at the last cultivation they will usually insure a good infection for cow peas the next year, and

the growth of cow peas in the corn may be worth more than the cost of seed, for the increased pasture provided for the cattle and hogs when they are turned into the stalk field, or for the organic matter and nitrogen added to the soil. We already have some evidence that a certain native legume and the cow pea are infected by the same bacteria. Investigations are now in progress to determine if this is true.

Alfalfa Bacteria.

These bacteria are not generally present in Illinois soils, but there are already in most parts of Illinois numerous fields of alfalfa well provided with bacteria. Furthermore this Experiment Station has shown that infected sweet clover soil is equally efficient for inoculating alfalfa fields. Because of this discovered relationship one seedsman now advises farmers to sow sweet clover where they later expect to sow alfalfa, evidently assuming that the bacteria will be generated spontaneously wherever sweet clover is seeded, and not realizing that sweet clover as well as alfalfa would need inoculation if seeded in an ordinary field where the bacteria were not present. This has been demonstrated by the Illinois Experiment Station by careful experiments conducted in 1903 and 1904, inoculation for sweet clover having markedly increased the yield.

Soy Bean Bacteria.

These are not present in Illinois soils as a rule, although there are now well infected fields at the University and in many other places in the state, from which infected soil can be obtained for inoculating other fields. Usually this will cost $1.00 to $2.00 per 100 pounds for collecting, drayage, bags and freight.

Any farmer can soon provide himself with sufficient infected soy bean soil to supply a township. Thus, if one scatters 100 pounds of well infected soy bean soil over a small plot of ground, say one-tenth of an acre, and then grows soy beans upon the land for one or two years, he could then supply a thousand bags of well infected soil from this plot.

Bacteria from the United States Department of Agriculture.

If anyone finds it too difficult or too expensive to secure infected soil containing the desired bacteria, he can easily obtain the artificial cultures by addressing the Secretary of Agriculture, Washington, D. C. The fact that the United States Department of Agriculture is prepared to send out free of charge cultures of bacteria for almost any desired legume is already widely advertised. It is also widely advertised that these artificial cultures are much superior to the natural soil bacteria,

but no such claim is made by the more conservative men in the Bureau of Plant Industry, under whose direction these artificial cultures are made.

In answer to a letter making definite inquiry regarding this point, Doctor A. F. Woods, Vegetable Pathologist and Physiologist of the Bureau of Plant Industry of the United States Department of Agriculture, makes the following statement, under date of April 20, 1904:

> "We do not maintain that the cultures distributed by us will produce a better inoculation than the old soil method, although we have cases where our cultures have produced better results than adjoining plots inoculated with soil."

Of course it might be added that in many other cases where comparative tests have been made the better results have been obtained by the use of infected soil. For example, Mr. Chas. A. Rowe, of Morgan County, Illinois, well known as a practical scientific farmer, writes as follows, under date of October 31, 1904:

> "On June 29 I got about a quart of soil from one of your plots on the University farm. I put it in a furrow and planted soy beans on June 30. I find nodules on every plant, as much as a tablespoonful on some. We got no results from the U. S. Government method of inoculation for soy beans. We could not carry out the directions exactly and possibly this was the trouble."

In the Farmers' Voice of January 14, 1905, is quoted a report of a comparative test with seed and soil inoculation carried out on the farm of Professor John Hamilton, Director of Institutes of the United States Department of Agriculture, the farm being located at State College, Pennsylvania. The report says:

> "Prof. Hamilton has not had heretofore very good success with alfalfa; so he determined to try inoculation both of seed and soil. He procured inoculated seed from the U. S. Department of Agriculture and to make sure he also sent to R. S. Seeds of Birmingham, Pa., and secured some dirt from his alfalfa field to sow on the plot . . . . .
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> "The soil, about ½-bushel, was sown on part of the plot before plowing. On part, because his farmer failed to go over more than probably one-third; just an irregular portion. After sowing he walked a few steps and then turned the box over and knocked the dust out of it. The plot was then plowed, harrowed and thoroughly prepared and then the seed was sown.
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> "At the time of our visit the part of the plot where

the soil was sown was as green as a meadow in June, while the balance of the plot was as bare as the road; the line being as distinct as could be, not just tapering off, but the plants just stopped at the edge of the untreated soil.

"The plot shows that in this case seed inoculation was a failure; while soil inoculation was a complete success."

In this instance we can hardly say that the farmer "failed to follow directions," because the seed itself had been inoculated by the U. S. Department of Agriculture. It may be added that the only important special claim made by Doctor Woods is that the artificial cultures prepared in his laboratories are superior to those prepared by Nobbe and others in Germany.

More Effective Nitro-Fixing Bacteria.

Even if it were possible to develop and maintain in the soil bacteria of greater nitrogen-fixing power it is a question whether the discovery would have great practical value (especially after the first year) for the simple reason that bacteria multiply with such tremendous rapidity that we may soon have many times the number of bacteria that are really needed to do the work. In other words the increase in numbers may result in just as great efficiency as would result from any increased power of the individual bacteria. One who carefully studies the formation of root tubercles on plants growing in soils in varying conditions or degrees of infection will observe that on plants sparsely infected the individual tubercles or clusters develop to enormons size, comparatively speaking; while in well infected soils the individual tubercles are much smaller and clusters scarcely form. It is also observed that the marked effect on the growth, color and composition of the plant is produced even though only a half dozen large tubercles form on the roots. It is very evident that the relationship between the bacteria and the host plant is such that if the soil is sparsely infected, so that the roots come in contact with but few bacteria and but few tubercles are started, those few tubercles will be so enlarged, either as individuals or as clusters, that the multiplication and activity of the bacteria are sufficient to meet the needs of the host plant so far as nitrogen is concerned. Of course, as soon as the soil becomes well infected the plant roots come in contact with large numbers of bacteria and many tubercles are formed, but most of them remain small, and no large clusters are formed, because the bacteria in the large number of small tubercles are apparently capable of furnishing all the nitrogen needed by the host plant. If the other

elements were provided in greater abundance, of course, the tubercles would undoubtedly become enlarged, as much as necessary to supply the nitrogen needed to balance the supply of the other plant food elements utilized by the plant.

For more specific information regarding nitrifying bacteria and nitrogen-fixing bacteria for different legumes, the reader is referred to Illinois Bulletin No. 94, which will be sent free of charge upon request to the Illinois Experiment Station, Urbana, Ill.